(2)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

AD-A241 260

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

ELECTE SEP 24 1991 S D

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
KATR8909-90-04-Z

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
Klein Associates Inc.

6b. OFFICE SYMBOL (If applicable)

7a. NAME OF MONITORING ORGANIZATION
U.S. Army Laboratory Command
Human Engineering Lab/SLCHE

6c. ADDRESS (City, State, and ZIP Code)
Yellow Springs, OH 45387-0264

7b. ADDRESS (City, State, and ZIP Code)
Aberdeen Proving Ground, MD 21005-5001

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL (If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
DAAA15-89-C-0505

8c. ADDRESS (City, State, and ZIP Code)

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Prototyping an Adaptive Decision Aid for Off-Road Navigation (Unclassified)

12. PERSONAL AUTHOR(S)
Leslie A. Whitaker

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Year One Final	FROM 8/89 TO 8/90	90 SEP 28	28

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A three-year project has been funded by the Human Engineering Laboratory to study off-road navigation. The goal of this contract is the development of a cognitive model of the off-road navigator. This model will take into account differences among individual navigators and their skill levels. The final product of this contract will be a prototype of an adaptive decision aid designed to support this navigation model. A paper prototype which illustrates the cognitive model will be developed. Klein Associates has completed the first year of work. This report describes the results of that year's effort.

91-11334

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Dr. Grayson Cuqlock-Knopp

22b. TELEPHONE (Include Area Code)
301-278-5988

22c. OFFICE SYMBOL

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

91 9 23 076

PROTOTYPING AN ADAPTIVE DECISION AID FOR OFF-ROAD NAVIGATION

Leslie A. Whitaker

Klein Associates Inc.
Yellow Springs, OH 45387

Accesion For
NTIS CRA&I ☒
DTIC TAB ☐
Unannounced ☐
Justification
By per form 50
Distribution /
Availability Codes
Dist | Avail and / or Special
A-1

September 28, 1990

DTIC QUALITY INSPECTED 3

The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

TABLE OF CONTENTS

PROTOTYPING AN ADAPTIVE DECISION AID FOR OFF-ROAD NAVIGATION

INTRODUCTION

What is Off-Road Navigation?

Navigation is the task of moving people and/or vehicles to a destination through various terrains. Off-road navigation is limited to areas which do not have vehicle roads. Therefore, off-road navigation may be conducted as cross-country marches with or without foot trails. The terrain may vary from featureless tundra to complex mountainous landscapes. Both individuals and groups of people may be navigating off road. They may be moving by foot or they may be moving in tracked or wheeled vehicles. Although aerial and ship navigation is technically "off road," the scope of the current project includes only ground navigators.

Navigation includes two general classes of activities: planning and executing the movement of people and/or vehicles. While some navigators may both plan and execute a route, often the planner and the executor are different people with different skills and perspectives. The scope of the current project is focused on the requirements of the navigators executing the route. That is, the focus of this project is to aid the tactical navigator. If this navigator is also the planner, then these planning needs are considered. However, the goals of the strategic planner are not within the scope of this project.

Currently, navigators have two primary types of tools: compasses and various maps. With these tools, navigators fix their own positions in space and determine the route to be followed to their destination. Unfortunately, many people have difficultly using maps for on-road navigation. Off-road navigation is an even more difficult and complex task. Moving through off-road terrain adds complexity to the navigation task in three ways: there is (a) an absence of signing, (b) a loss of familiar manmade cues, and (c) the addition of a third dimension-- elevation. The goal of this project is to aid the navigator by examining innovative means to provide critical cues.

These new tools should support the navigator in making on-the-spot decisions about location and route choices. They must be designed to provide navigators with information as it is needed and in a form which can be easily used. Since navigators' needs differ as a function of their current tasks and of each navigator's own skill level, these tools should be adaptive and flexible. These criteria can be met by the development of a decision aid. Current computer technology can be employed to produce electronic decision aids to support decision makers for various tasks. The objective of the present project is to provide pre-design data and prototype screens for a computerized decision aid for the off-road navigation task.

What are Computer Decision Aids?

Computerized decision aids are a broad class of tools that allow the human operator and a mechanical portion of the system (the computer) to interact, by sharing the information load in reaching a decision. The terminology used in describing many aspects of human-computer interactions is quite loose at this time Various authors use such terms as intelligence, decision support, adaptive, artificial intelligence, expert system, and user-computer interface in their own (often conflicting) ways. Hence, we will define the terms that we are using as they occur in the text.

Computer aids have been classified in a variety of ways. For the purposes of this report, two classifications will be used. First, decision aids can be divided into Expert Systems and Decision Support Systems (DSSs). Second, these systems may be static, or they may be adaptive to the operator, possibly "learning" during the course of their use.

Expert System vs. Decision Support System

Expert Systems replace the operator in the decision loop. The operator enters conditions and parameters and then the computer analyzes, applies relational rules, and produces a decision. The AALPS loadmaster expert system (Klein, 1987) prepares loading manifestos for air cargo transport. Although a loadmaster has the final say on the adequacy of the load plan, AALPS is the system which generates that plan. These systems have been described as "putting the expert in a bottle" by capturing the operator's knowledge and codifying it into the computer.

In contrast, Decision Support Systems are designed to aid the operator, who is still responsible for arriving at the final decision. For example, Brigade Planner is a DSS which aids C^2 planners in developing operations orders. The planner uses the computer program to calculate line of sight for firing positions, location of high speed avenues of approach, speed of unit movement, etc. All of these calculations are time consuming and prone to error when handled by the human operators (staff planners). When the humans work in conjunction with the computer, their information load and time constraints are eased, thereby improving the quality of their decisions (Thordsen, Brezovic, & Klein, 1988).

Static vs. Adaptive

Static decision aids are designed for a general class of users. They do not learn (alter their activities) on the basis of previous interactions with users. They may or may not be able to acquire new data, but they cannot adjust their decision rules or their method of interacting with the operator. Static decision aids usually employ conventional programming, in contrast with artificial intelligence programming used to produce intelligent behavior in adaptive systems (Shoval, 1986).

Adaptive systems learn as a result of their interactions with various operators. Some adaptive systems restructure their interfaces to become more user friendly for novices (Rissland, 1984). Specifically, menus and graphics are used instead of operations prompts (Badre, 1984). Others can develop new rules as a function of the paths, nodes, and relationships which the user accesses. Thus, the decision aid is "smarter" about the domain after each interactive session with an operator (Harmon & King, 1985). Finally, the system may adjust the types and depths of information made available to the user on the basis of that particular user's skills, needs, and mental model of the problem area (Peachey & McCalla, 1986).

Some authors disagree with the need for adaptive systems (e.g., Lehner & Zirk, 1987) and others question the current feasibility of developing effective adaptive programs (Rouse & Morris, 1986). However, the most common opinion among human factors professionals is that good adaptive decision systems will be significantly better than static aids (Huchingson, 1981; Kantowitz & Sorkin, 1983; Landy & Trumbo, 1976; Lee, 1971; Rouse & Boff, 1987; Sanders & McCormick, 1987). A key element of this statement is the word "good." Adaptive systems which are not correctly meshed with the operator's performance add just one more degree of uncertainty. Under those conditions, it may be better to have a static system whose performance can be learned, rather than an "adaptive" system which is really a loose cannon on deck.

DESIGNING GOOD ADAPTIVE DSS

The scientific community of psychologists, systems engineers, and computer programmers is presently confronted with the task of designing good adaptive DSS. Although initial work has begun in this area, a great deal of effort must still be expended. Gaines and Shaw (1986) have proposed that empirical human factor studies provide insufficient guidance for systems design. They argue that the components necessary to develop satisfactory human-computer systems are in varying states of development. The human-computer interface (i.e., the DSS) is in the theoretic stage which requires work beyond empirical investigation. It is time to stop running yet one more experiment, and instead to focus on specific theoretical questions. We will address the following in the current project:

- determine critical criteria for adaptive systems
- determine accurate mental models of the users
- determine the characteristics of a domain for successful application of an adaptive DSS
- conduct the knowledge engineering for eliciting the expertise of this domain
- evaluate the success of the resulting DSS.

Critical Criteria for Adaptive Systems

Currently, criteria for DSS are either written in broad, general terms which are difficult to implement: e.g., Determine the user's goals (Card, Moran, & Newell, 1983) or The system must understand the user (Halpin & Moses, 1986); in theoretical terms which lack a specific translation: e.g., The human needs to explain and to make sense out of experiences with the systems (Norman & Draper, 1986); or in terms too specific to the system and which may be misleading outside of the specific domain: e.g., ZOG is based on the concept of menu-selection with a vast database of menus (McCracken & Akscyn, 1984).

The guidance requested by Gaines and Shaw (1986) is to bring the development of DSS to the level of automation, where theories predict experience and generate rules. We feel that the field's ability to accomplish such automation is several steps removed from the current situation. The first step toward accomplishing this goal is the development of testable criteria, which guides DSS developers in the selection of appropriate application domains.

Users' Mental Models

Mental models are descriptions of the user's understanding of his/her task and of the DSS's operation. These two aspects of the user's mental model are of interest to cognitive psychologists and systems developers. Cognitive psychologists want to know how the user engages in the process of decision making itself. In contrast, systems developers are very interested in the user's perception of the DSS's operation; what is the user's model of the system.

Decision-making models. Consider first the cognitive psychologist's interest. Mental models of decision making have been proliferating for the last quarter of a century. Currently there is strong disagreement about analytical models which view the user's brain as a computer, a calculating machine. This metaphor is the basis for much information processing and artificial intelligence (AI) research. A basic assumption is that intelligent outputs can be described in terms of specifiable procedures operating on atomistic pieces of information. Skilled performance consists of learning high-order procedures, adding more and more bits of information, and gaining efficiency in carrying out operations. Hence, better solutions are those which apply more analytical processes, and a good decision maker will employ such analytical processes in solving problems. It is a very small step from this assumption to the conclusion that a DSS should provide atomistic information, suitably calculated and massaged, for the user.

Other investigators have found evidence that more highly practiced skills performed by more experienced people show less influence of analytical processes (Hammond, 1980, Klein, 1989; Sage, 1982, Shanteau, 1985, Shiffrin & Schneider, 1977). Much of what we call expertise is the ability to match patterns (Klein & Calderwood, 1986, Rouse & Hunt, 1984). Expert decision making in this model is not a reductionist, analytical process. It is a very small step from this assumption to the conclusion that a DSS should provide patterns of events as data. In fact, Klein Associates has recently completed such a system for Air Force Weapons Laboratory (AFWL) and another for the Defense Advanced Research Projects Agency (DARPA). These DSSs rely on a database of cases drawn from the domain's prior history. With the help of the DSS, the user accesses database cases which help to answer the current problem.

A third mental model that is proposed by multi-attribute utility theory (MAUT) The MAUT model states that the good decision maker proposes a number of alternative options, weighs the attributes of those options, and selects the option which scores highest. Some authors have argued that people "fail" to achieve this normative model (Coombs, Dawes, & Tversky, 1970) because of information-processing limitations. However, our experience in the study of experts in naturalistic settings has shown a very different approach to decision making.

User's model of the DSS. The systems analyst is interested in the user's understanding of the workings of the DSS. The user views the DSS through its user-computer interface (UCI). The opacity or transparency of this interface determines the extent to which the user can understand this decision aid. Lehner and Zirk (1987) provided evidence that the user's mental model of the system's operating processes was even more important in determining performance than was the consistency between the user's problem solving techniques and that of the DSS. The user does develop a conceptual model reflecting his understanding of the system operation. The extent to which this conceptual model reflects the user's task, its requirements, and the system's capabilities will determine the sophistication with which the user can interact with the support system (Norman & Draper, 1986). Furthermore, when the system is responsive to the particular user's background, automation skills, and prior experiences with this DSS, it can be designed as an adaptive system.

Some aspects of UCI design which are termed "user-friendly" reflect the efforts on the part of the designer to increase the transparency of the interface. These are described extensively in Smith and Mosier's (1986) design guidelines. However, the aspect of mental models which is still quite controversial is the degree to which the user should be informed of the inner workings of the DSS. One guideline can be used to illustrate this balance. Do inform the user of the basis for the decision, but do not display information about the system status details. Hence, in a case-based DSS we developed for engineers, we displayed a message to explain the selection of a prior case.[1] In order to help the engineer understand the model by which SURVER II selected this prior case from the database, the following type of information was displayed for critical attributes:

> New T over R ratio's value is 0.4 and the log difference is 7.3518-01 from the prior case value 0.216 and the weight for the attribute is 10 and this is an important retrieval attribute.

The type of system status details that we elected not to display would include "loading file INIT.FAS" or "reading file C:\GWZ\USERINIT.LSP." Instead we provided the message "Working, Please wait" to explain that the system was functioning.

Rouse and Morris (1986) have offered a cautionary note about the issue of mental models. At this time, there is not only a lack of consensus, but even the terms lack explicit definitions. They caution that mental models are likely to be dynamic in nature, prone to reinterpretation through researchers' bias, and difficult to elicit from the subject matter experts (SMEs). This review is consistent with our own cautious approach to finding THE SOLUTION to the question of mental models. It may not be possible to ascertain the "truth" in mental models, but research should be done to provide guidance sufficient to direct our efforts in DSS development. This is a pragmatic solution and is the one addressed in the scope of the current project.

Determine Criteria of an Appropriate Test Domain

Not all problem domains are appropriate for the use of a DSS. For example, domains which are primarily graphic suffer from the need for extensive memory capacity to digitize, store, search, and retrieve this graphic information. For some systems, the inherent limitations of the knowledge in the domain will encourage the use of one type of DSS in preference to others. We found that the domain of structure survivability required a combination of two types of DSS systems. A large CRAY mainframe computer to run SAMSON code was used to determine analytical solutions to some aspects of the problem. However, the remaining engineering decisions suffer from fuzzy sets and will not yield to algorithms. These decisions are now supported by our DSS (SURVER II). Consequently, it is necessary to determine the constraints of the specific domain and develop a DSS which will match those needs.

---

[1]The engineer's task was to determine whether a specific test structure would survive a given blast intensity. The engineer used a DSS called SURVER II to analyze his test case. When the test case was entered into the system, SURVER II selected a prior case from the data base on the basis of several physical attributes (e.g., blast intensity, diameter, radius, presence of SALT ports, burial depth). This prior case and its survivability results were displayed for the engineer. He then decided whether his test structure was more or less likely to survive its planned blast exposure.

Knowledge Engineering Techniques and Machine Intelligence

Knowledge engineering is the most costly component in the development of a DSS (Boose & Gaines, 1986). Efforts in the AI field are being expended to streamline knowledge-engineering efforts. Surface knowledge in the form of standard operating procedures or written procedures can be obtained relatively quickly and easily. The deeper knowledge which actually constitutes the experienced person's expertise is much harder and more frustrating to obtain. Klein Associates employs knowledge elicitation interview techniques aimed at obtaining this deeper knowledge efficiently. The interviewer asks the domain expert to describe a specific incident in his/her experience. The incident revolves around a decision made by the expert. The interviewer then probes the description by asking for the knowledge which led to that decision. This method is a variation of the critical incident technique reported by Fitts and Jones (1947).

The following example serves as an illustration of that critical incident method. The objective of the question was how experienced navigators determine their geographic position. A navigator who had been a radio operator in Vietnam was being interviewed. He was asked to describe an incident in which he had had to determine his position exactly. He described the placement of an antenna at a transmission site in Vietnam. The transmission beam is very narrow and requires exact placement; therefore, the operator was using his skills as a navigator to determine his exact location and the planned location of the radio receiver. The mountainous and forested terrain provided distinctive geographic contours but few means of obtaining precise location He explained that he used the method of triangulation to determine his location. His initial responses described the trigonometry of this method but did not reveal the way in which he obtained the triangulation points. During the interview, subsequent probe questions were used until the operator was finally able to describe how he selected these points. He used distinctive point features which had often been noted by previous radio operators on their topographic map. The critical breakthrough in the interview occurred when he said, "It was better to have an old map." Probes which followed this statement revealed the importance of the prior experience contained in the penciled notes made by previous operators. There were "crooked tree," "old burn," and even "wash on line" notes which helped the radio operator select specific features to use as triangulation points.

The critical incident method has allowed Klein Associates to develop unique methods for studying the nature of highly proficient performance. During the development of these methods, it has become very apparent that decision aids, computerized or not, must provide support for the way in which the operator functions. These decision aids must work consistently within an accurate cognitive model of the operator's task. Without an adequate theory of human decision making, the development of automated decision aids is extremely risky. At the least, a descriptive model of the navigator's decision-making task must be used to guide the development of the proposed decision aid.

In summary, these knowledge-engineering techniques have been used in the present project to allow a precise and detailed description of navigator performance. This description will be the basis of the navigator's cognitive model and will be used to guide the development of the decision aid prototype in subsequent years of this contract.

System Evaluation

How can the navigator's new DSS be evaluated? The performance with and without the decision aid can be compared, once the DSS has been developed. However, it would be desirable to evaluate the DSS during its conceptual development. Klein Associates has developed a method for measuring the task performance of expert systems which can be applied either to a fielded system or to a potential system in its conceptual design stage. Evaluation during the conceptual stage can be accomplished using prototypes of the screens (storyboards) and descriptions of the DSS actions. The evaluation will allow both the developers and the government, as the sponsors, to make better decisions about how to implement this DSS and how to integrate it into organizational operations. In essence, the method determines the "intelligence quotient" of specific AI applications, and is therefore, an AIQ™ test. The competence of the system (or potential system) is measured in two ways: 1) by identifying critical performance incidents that show the major differences between navigators using conventional tools and navigators using the DSS, and 2) by providing a set of ratings for the system: for its performance, for its effect on the performance of the navigators using it, and for its effect on organizational performance.

CONTRACT WORK COMPLETED TO DATE

In order to accomplish this contract's goals, a two-pronged approach was used. First, Klein Associates conducted a series of interviews with navigators (orienteers). Human Engineering Laboratory (HEL) transcribed these interviews and is in the process of coding them for analysis of the cues and strategies used by orienteers. Second, HEL, with the assistance of Klein Associates, has designed and is preparing to conduct two experiments. The objective of these experiments is to provide insight into the cognitive processes used by navigators.

Orienteering Interviews

Sixteen critical incident interviews with orienteers were conducted. Three of these interviews were conducted in Maryland at the Aberdeen Proving Ground. The remaining interviews were conducted in Ohio.

The central focus of these interviews was to pinpoint the perceptual cues used by experienced and less experienced travelers in finding their way during off-road navigation. People differ in their ability to navigate successfully (Chase & Chi, 1980; Sholl, 1988; Streeter & Vitello, 1986). Chase and Chi attribute these individual differences to experience, while Sholl attributes them to innate characteristics. Streeter and Vitello find that both experience and innate abilities produce differences in navigational skills. The interviews conducted in the current effort examined the influence of experience on one aspect of off-road navigation–the use of perceptual cues.

The major hypothesis is that limited sets of visual cues are used by orienteers. While these cues may change with experience level, cognitive style, or other personal variables, we predict that the sets will exist and will be specifiable (Goldin & Thorndyke, 1982; Wickens, 1984). The goal of these interviews was to determine the visual cues which must be made available by a decision support aid. If we do find individual differences, one way in which this decision aid must be adaptive is with respect to the cues which it provides to different users.

Procedure and methodology. Orienteers were selected from Dayton and Cincinnati orienteering chapter membership lists. Interviews were conducted individually. Each interview required 1-1/2 hours. All but one orienteer participated in a single interview. That one orienteer participated in two interviews. In addition, some follow-up telephone calls were made to supplement these personal interviews. The telephone calls were limited to the clarification of details.

It is recognized (Waterman, 1986) that much of expert knowledge is tacitly held, often involving skills so well learned and familiar to experts that they may not be consciously aware of drawing on that knowledge in the course of performing some task. Chase and Chi (1980) describe spatial skills as belonging to these domains of tacitly held expert knowledge. Knowledge elicitation methods that focus on making tacitly-held knowledge explicit can provide information on expertise that is unavailable from the spontaneous verbal reports of experts (Andriole, 1989; Hopple, 1986).

The Critical Decision method (CDM) is such a knowledge elicitation tool. For these interviews, the CDM was used to identify key decision points in off-road navigation. The interviews elicited the perceptual cues that surrounded each decision points and described the linkages among these various cues.

CDM is a semi-structured interview technique that employs specific, focused probes designed to elicit particular types of information from the interviewee. Solicited information includes the following: goals that were considered at the time of the incident, options that were evaluated and how they were chosen; perceptual cues utilized, contextual elements and situation assessment factors specific to a particular decision.

The interview data were obtained in the following manner. The orienteer was asked to describe two types of experiences:

(1) A normal orienteering course choice point;

(2) A particularly challenging situation in which her/his skills made a difference in the navigation outcome.

Each incident was described in a chronological fashion from the first relevant input to the conclusion (and feedback of success or failure). The timeline of events indicated whether this incident was a single decision point (with its own discrete set of critical visual cues) or whether it was a series of two or more choice points. Next, each choice point was probed to obtain a description of the manner in which the perceptual cues affected the decisions made. The goal of these interviews was to specify the critical visual cues which must be made available to an off-road navigator.

The following incident illustrates the type of probes used to elicit perceptual cues and link them to the navigation choice. Suppose that the orienteer has related the following information about a non-routine incident:

> As I approached the trail intersection, something didn't look right, so I took a compass reading and found out that I was 20 degrees off the path I thought I was taking.

Examples of probes used for perceptual cues are:

Probe 1: You said that "something didn't look right." Tell me more. [Interviewer has heard a visual cue but doesn't know whether it was on the path, in the landscape, or whether this is a use of the word "look" to mean "seem" or "feel," etc.]

Response: The lay of the land wasn't what I expected.

Probe 2: How did it differ from what you expected? [Probe for color, texture, size, shape, slope, landmarks, etc.]

Response: I don't know. It just didn't look right.

Probe 3. Would I be able to see the difference myself? [Probe 2 hit a snag. Interviewer is using a different tack.]

Response. Yes, but only if you were looking for it. See, the hills in that country slope pretty consistently to the Northeast. That means that I should have had valleys opening up regularly on my left. But they weren't.

Subsequent probes were used to specify the slope cue and the duration of the information (i.e., how many valleys had he passed? How far ahead could he see?). This information will be critical in determining the information which must be provided by a decision aid to the navigator.

A second set of probes was triggered by the orienteer's comment on the compass reading. This time the probes were designed to determine how the orienteer decided that his situation assessment was faulty and how corrective information (via compass, map, or radio) was gathered.

Analysis plan. The orienteers' responses are being coded by cue category and strategy used from transcripts of the verbal protocols. These categories will determine the critical cues used by experts and novices. The categories include ground-based cues, landmarks, depth perception, inferred cues, and complex cues. In addition, categories of tabling strategies, hypotheses, and objectives will be examined. Cues were assigned to categories by one primary rater. A second rater will independently code 25% of the data to assess interrater reliability.

Based on the interview data, we plan to develop a Perceptual Cue Profile that identifies and describes decision points, critical cues, and contextual factors surrounding off-road navigation. The information gained from these interviews will be used in the development of guidelines for the proposed DSS.

On the basis of our initial examination of these interviews, we have found that orienteers do use perceptual cues which can be provided in both text and graphic form by a decision aid. Various rules of thumb have been found to be common across orienteers. For example, "Stay high to survey the terrain." However, such rules may be in conflict with one another; for example, "Avoid elevation change" and "Maintain concealment" mitigate against the "Stay high..." rule.

Two Laboratory Studies

Initially, HEL had planned to conduct a remote driving-field study at the driving range at Aberdeen Proving Ground. The goal of this study was to test the effects of field of view (FOV) and driver's point of view (outside-in vs. inside-out). However, after initial investigation of this study, the Contracting Officer's Representative (COR) decided to replace this field study with a laboratory study of driver's use of perceptual cues. This change was necessitated by more recent developments in the literature and by equipment limitations at HEL.

The laboratory studies have been designed to measure two factors: (a) individual differences in navigational abilities and (b) the effects of limiting perceptual cues which provide visual information.

Individual differences. A review of the cognitive literature showed that there are individual differences in navigational skills (Chase & Chi, 1980; Goldin & Thorndyke 1982; Sholl, 1988; Streeter & Vitello, 1986; Wickens, 1984). The appropriate psychometric tools for assessing these individual differences are currently being debated in that same literature. The HEL laboratory study will address this issue by using a battery of psychometric tests and measuring reported sense of direction, as well as measuring task performance.

Visual resolution. The second variable of interest is the consequences of limiting perceptual cues on navigational performance. When operators are controlling remote vehicles or when in-vehicle drivers must function using television or other sensors (instead of directly observing their environment), what are the consequences of having less than optimal visual information from the displayed scene? For remotely operated vehicles, field of view and resolution must be limited to maintain a narrow band width or a small electronic signature. For in-vehicle operation, less fidelity (again, smaller field of view and less resolution) will allow the use of less expensive equipment. Unfortunately, we do not currently know the performance consequences of these display degradations. The goal of the current research program is to learn the minimal set of perceptual cues needed by an off-road navigator to maintain satisfactory performance. Therefore, this pair of laboratory studies will examine the consequences of limiting visual information in two ways (1) resolution of the visual image will be varied, and (2) color vs. black-and-white displays will be tested.

Examples of the Stimulus Materials are included in Appendix A. The Stimulus Materials provide examples of the varied levels of resolution which will be tested.

The two laboratory studies are currently planned to begin during the next quarter. They will be conducted at HEL by the COR using military subjects. Klein Associates has been providing assistance in the development of these two studies and will continue to do so.

Year One support tasks. At the end of the first year of this contract, the following activities had been completed by the COR with support from Dr. Whitaker of Klein Associates:

Literature Review:	A literature review was conducted prior to the design of these studies. Additional information is included as an Annotated Bibliography in Appendix B.
Problem Statement.	Problem statement and research hypothesis related to individual differences and limited perceptual cues were completed. This information is included in the Research Protocol submitted to the HEL review panel.
Procedure.	Research procedures including the battery of psychometric tests and the appropriate resolution levels to be tested were obtained.
Protocol Approval:	This protocol was approved by the HEL Research Committee. Such approval is necessary prior to the conducting of any in-house HEL research.
Stimulus Materials:	Photographs of the test scenes were made during a site visit to HEL by Dr. Whitaker. Each site was photographed from eight compass positions. From the possible sites photographed by Drs. Whitaker and Cuqlock-Knopp, the test set was selected for development as stimulus material. HEL developed these photographs as slides to be used in the studies. Each photograph was reproduced as a slide at each level of visual resolution.
Subjects:	Military personnel currently enrolled in the Ordinance School's Navigation course will be the subjects in these studies.

Publications Resulting from Year One Effort

Two papers were written to describe our work on this contract. Copies of these two publications are included as Appendix C.

"Adaptive Decision Aiding for Off-Road Navigation" was co-authored by Dr. Whitaker and Dr. Cuqlock-Knopp for a presentation at the 7th Annual Joint Services Workshop on C^2 Decision Aiding at Wright Patterson AFB, Dayton, OH. This paper describes the importance of navigation as a component of the many tasks critical to C^2. The role of perceptual cues, individual differences in navigators' skills and abilities, and visual resolution and field of view in navigator information needs were all discussed.

A summary describing the goals of the navigation project was published in the June, 1990, HFS Visual Performance Technical Group Newsletter. The newsletter contained "Look Where We're Going," which served as an announcement of this contract and an invitation for other investigators to contact us with descriptions of their work in progress. To date, three investigators have contacted us with interesting work-in-progress of their own. We plan to continue this communication with the field during the remainder of this contract.

Work Remaining to be Completed

In the original Statement of Work, we had anticipated completing additional work with these interview data by the end of the first year. These interviews are currently being coded by the HEL team and will be made available to Klein Associates in the next quarter. There are three tasks remaining in the first year plan. We anticipate being able to complete these tasks within the budget for this phase of the contract. We do not anticipate that these scheduling changes will prevent the completion of this total contract on time and within budget.

We plan to complete two tasks of the Year One Statement of Work during the next quarter:

1) Provide a written model of the navigator's use of perceptual cues and strategies. This will be provided as a technical report co-authored by Klein Associates and HEL.

2) Develop storyboards of proposed decision aid computer screens. These storyboards will be evaluated by a sample of orienteers and modified by Klein Associates.

The third task requires that we have input from the pending HEL experiments in addition to the results of the orienteering interviews:

3) Write a report describing navigator's cognitive model based on these modified storyboards and the results of the two pending HEL experiments.

REFERENCES

Andriole, S. J. (1989). Methodologies for computer assisted decision-making. In W. B. Rouse (Ed.), Advanced in man-machine systems research, 1-45.

Badre, A. (1984). Designing transitionality into the user-computer interface. In G. Salvendy (Ed.) Human-Computer Interaction. Elsevier Science Publishers.

Boose, J. H., & Gaines, B. R. (1986). Proceedings of the Knowledge Acquisition for Knowledge-Based Systems Workshop, American Association for Artificial Intelligence. Banff, Alberta, Canada, Nov. 12-7.

Card, S. K., Moran, T. P., & Newell, A. (1983). The psychology of human-computer interaction. Hillsdale, NJ: Lawrence Erlbaum Associates.

Chase, W. G. & Chi, M. T. H. (1980). Cognitive skill: Implications for spatial skill in large-scale environments. In J. Harvey (Ed.), Cognition, social behavior, and the environment. Potomac, MD: Lawrence Erlbaum Assoc.

Coombs, C. H., Dawes, R. M., & Tversky, A. (1970). Mathematical psychology. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Fitts, P. N., & Jones, R. E. (1947). Analysis of factors contributing to 460 "pilot-error" experiences in operating aircraft controls. In H. W. Sinaiko (Ed.), Selected papers on human factors in the design and use of control systems, (1961), 332-358. NY: Dover Publications.

Gaines, B. R., & Shaw, M. L. G. (1986). From timesharing to the sixth generation: The development of human-computer interaction. International Journal of Man-Machine Studies, 24.

Goldin, S. E., & Thorndyke, P.W. (1982). Simulating navigation for spatial knowledge acquisition. Human Factors, 24, 457-471.

Halpin, S. M., & Moses, F. L. (June 1986). Improving human performance through the application of intelligent systems. Signal.

Hammond, K. R. (1980). The integration of research in judgment and decision theory (Report No. 226). Boulder, CO: Center for Research on Judgment and Policy.

Harmon, P., & King, D. (1985). Expert systems: AI in business. NY: Wiley Press.

Hopple (1986). Decision aiding dangers: The law of the hammer and other maxims. IEEE Transactions on Systems, Man, and Cybernetics, SMC16, 948-964.

Huchingson, R. D. (1981). New horizons for human factors in design. New York, NY. McGraw-Hill Book Company.

Kantowitz, B. H., & Sorkin, R. D. (1983). Human factors: Understanding people-system relationships. New York, NY: John Wiley & Sons.

Klein, G. A. (1989). Recognition-primed decision. In W. Rouse (Ed.), Advances in Man-Machine Systems Research, 5, 47-92. Greenwich, CT: JAI Press, Inc.

Klein, G. A. (1987). AIQ: A test for the performance of expert systems. Proceedings of the AOG/AAAIC 87 Joint Conference. OH: Dayton. Also published in U. Gupta (Ed.), Validation and verification of knowledge-based systems. Los Alamitos, CA: IEEE Computer Society Press, 1990.

Klein, G. A., & Calderwood, R. (1986). Human factors considerations for expert systems. Proceedings of IEEE National Aerospace and Electronics Conference, NAECON, 3, 921-925.

Landy, F. J., & Trumbo, D. A. (1976). Psychology of work behavior. Homewood, IL: The Dorsey Press.

Lee, W. (1971). Decision theory and human behavior. New York, NY: John Wiley & Sons, Inc.

Lehner, P. E., & Zirk, D. A. (1987). Cognitive factors in user/expert-system interaction. Human Factors, 29-1, 97-109.

McCracken, D. L., & Akscyn, R. M. (1984). Experience with the ZOG human-computer interface system. International Journal of Man-Machine Studies, 21.

Norman, D. A., & Draper, S. W. (Eds.) (1986). User centered system design: new perspectives on human-computer interaction. Hillsdale, NJ: Erlbaum.

Peachey, D. R., & McCalla, G. (1986). Using planning techniques in intelligent tutoring systems. International Journal of Man-Machine Studies, 24, 77-98.

Rissland, E. L. (1984). Ingredients of intelligent user interfaces. International Journal of Man-Machine Studies, 21.

Rouse, W. B., & Boff, K. R. (Eds.) (1987). System design: Behavioral perspectives on designers, tools, and organizations. North Holland: Elsevier Science Publishers.

Rouse, W. B., & Hunt, R. M. (1984). Human problem solving performance in fault diagnosis tasks. In W. B. Rouse (Ed.), Advance in man-machine systems research, 1, 195-222. Greenwich, CT: JAI Press Inc.

Rouse, W. B., & Morris, N. M. (1986). On looking into the black box: Prospects on limits in the search for mental models. Psychological Bulletin, 100,(3), 349-363.

Sage, A. P. (1982). Behavioral and organizational models for human decision making. Proceedings of the IEEE Conference on Decision and Control.

Sanders, M. S., & McCormick, E. J. (1987). Human factors in engineering and design, Sixth Edition. New York, NY: McGraw-Hill.

Shanteau, J. (1985). Psychological characteristics of expert decision makers. Kansas State University Psychology Series, No. 85-2.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing. II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 84, 127-190.

Sholl, M. J. (1988). The relation between sense of direction and mental geographic updating. Intelligence, 12, 299-314.

Shoval, P. (1986). Comparison of decision support strategies in expert consultation systems. International Journal of Man-Machine Studies, 24, 125-139.

Smith, S. L., & Mosier, J. N. (1986). Guidelines for designing user interface software (ESD-TR-86-278). Bedford, MA: MITRE Corp.

Streeter, L. A. & Vitello, D. (1986). A profile of drivers' map-reading abilities. Human Factors, 28, 223-239.

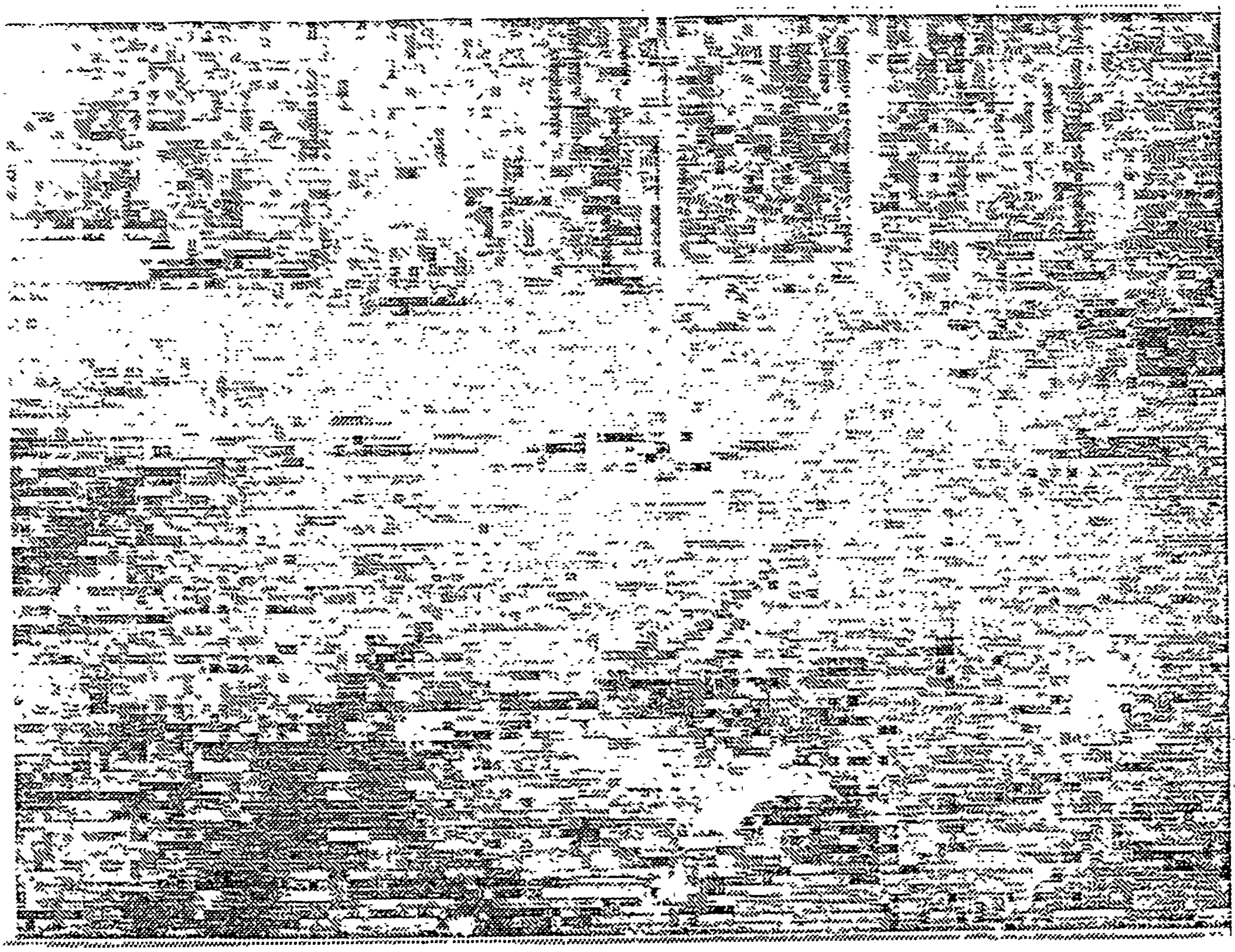
Thordsen, M., Brezovic, C. P., & Klein, G. A. (1988). Knowledge elicitation study of command-and-control decision making. Working paper. Yellow Springs, OH: Klein Associates Inc.

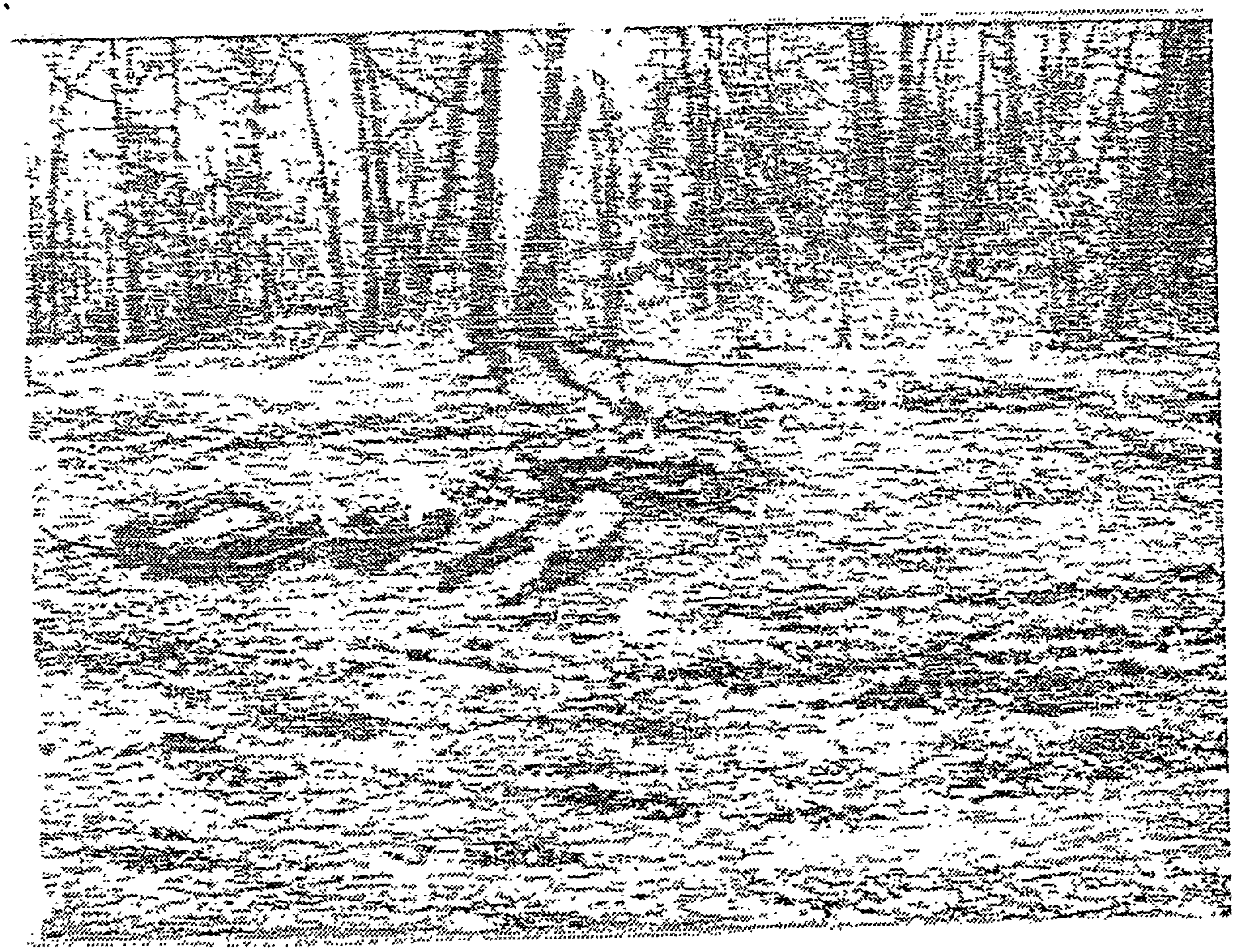
Waterman, D. A. (1986). A guide to expert systems. Addison-Wesley Publishing Company, Inc.

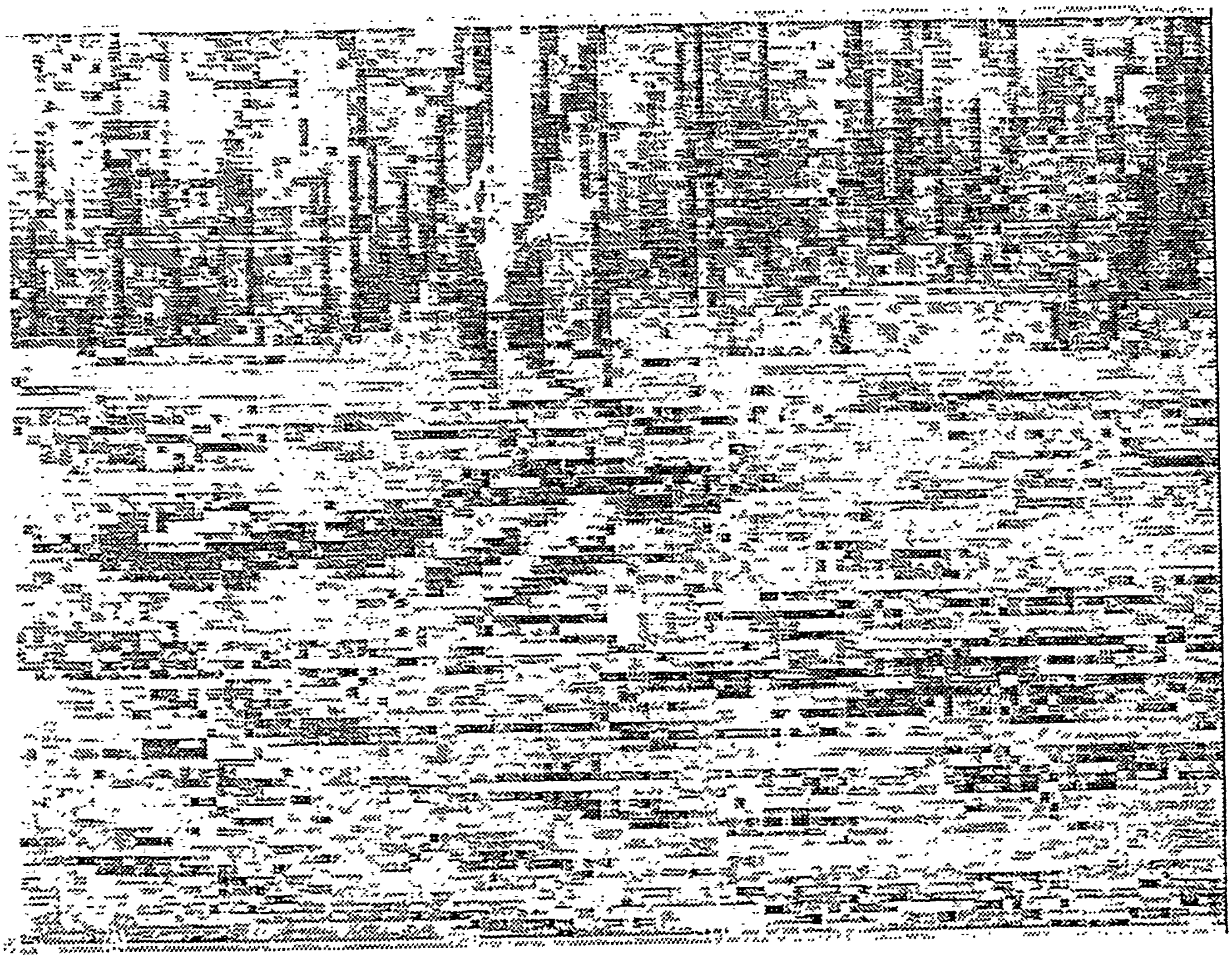
Wickens, C. D. (1984). Engineering psychology and human performance. Columbus, OH: Charles H. Merrill Pub. (pp. 183-193).

APPENDIX A: STIMULI

Two Scenes are shown at three levels of resolution.







APPENDIX B: ANNOTATED REFERENCES

Chase, W. G. & Chi, M. T. H. (1980). Cognitive skill: Implications for spatial skill in large-scale environments. In J. Harvey (Ed.), Cognition, Social Behavior, and the Environment. Potomac, MD· Lawrence Erlbaum.

Chase and Chi reviewed studies of perceptual skills from a variety of domains (chess and other board games, physics, architecture, circuit diagrams). In each, they found that experts have higher levels of organization for their domain than do novices. Lower levels of organization emphasize structural cues, while higher levels emphasize functional ones. They describe a fast-access pattern recognition process which is common to experts in all these domains. They caution that it is difficult to predict whether a person will develop a high level for a complex skill (e.g., tennis)--either by noting his/her abilities on basic component skills (manual dexterity--eye-hand coordination) or by noting ability in a related complex skill (racquetball). Specific to the area of map reading, this article discusses two points: (1) Information is stored in a hierarchical fashion. Global features are stored and local features are inferred from this global structure. (2) Cognitive map structures matter for correct navigation. While people may be able to move along a specific route, they cannot navigate a new route if their global structure is incorrect (e.g., navigate to San Diego from Reno). Route and survey knowledge are discussed. Route knowledge allows a traveler to follow a specified path. Survey knowledge allows a navigator to reach a destination using an uncharted path. Processes used in navigation can be divided into two types: automatic and inference rules. The automatic processing may occur as follows: You are following a well-known route. At each choice point, you recognize a set of stored visual cues and then decide upon your path. The inference rules are used to fill in "gaps in routes, orient oneself in the environment, perform geometric problem solving" (p. 27). I assume that these rules are better developed in experienced orienteers than in novices. Note definition of cognitive map on p. 29 (from Downs & Stea, 1973). Also note caution that a cognitive map is NOT held in the head of a navigator and that an average cognitive map does not describe the thinking of any one navigator.

As a quick test of Chase and Chi hypothesis, I asked a nonrandom selection of Midwesterners the following question:

"Where is San Diego from Reno?" All 11 people marked SW. San Diego is actually SSE of Reno.

Sholl, M. J. (1988). The relation between sense of direction and mental geographic updating. Intelligence, 12, 299-314.

This article describes a view different from Chase and Chi. Sholl proposes that people with a good sense of direction differ from those with a poor sense of direction. This difference is found in basic psychophysical measures of innate abilities.

Streeter, L. A. & Vitello, D. (1986). A profile of drivers' map-reading abilities. Human Factors, 28, 223-239.

People know whether they have a good sense of direction. Such people are better at distance estimation, like using maps, as well as giving and following directions, and can point to unseen buildings. However, this appraisal is not correlated with pointing to compass directions. Thorndyke has found no correlation between map-reading and map-learning (memory task) skills. [Note: Sholl and Egath (1982 Cognitive correlates of map-reading ability. Intelligence, 6, 215-230) found that ability to read a contour map was correlated to general problem solving skills, not to spatial ability.] Expert vs. novice use of the road systems found that experts use the secondary roads more. In an actual driving task, locations of major landmarks were not coded by compass direction but instead by the direction of the road that led to the landmark. (These findings are from their literature review.) EXPERIMENT I: A battery of tests for various navigational and cognitive skills were run. There are good citations to the tests used in this battery.

It required approximately one hour and 45 minutes to run the battery. Subjects were tested in groups. Some results: People who use maps infrequently prefer verbal directions and use landmarks more than people with more map-use experience. EXPERIMENT II: Expert, experienced, and novice travelers drew routes. The maps did not provide color and poor map readers tended to use county boundary lines as roads. CONCLUSIONS: Poor map-users rely on all types of landmarks equally. They navigate by moving from landmark to landmark. Good map-users designate rivers and railroads as better landmarks. A poor navigator is as lost two blocks from the route as 20 km from the route.

Wickens, C. D. (1984). Engineering psychology and human performance, 183-193. Columbus, OH: Merrill Pub.

There is a subsection titled "Space Perception, Maps, and Navigation" in which Wickens argues that spatial skill is a different skill than is verbal skill. He uses Thorndyke's work to support the spatial vs. verbal abilities as determiners of skill level. NOTE: Chase and Chi say that verbal and spatial skills are all of a piece. Wickens argues that novices work from landmark and route information, while more experienced navigators work from survey knowledge. Survey knowledge is good for getting the whole picture and for planning. People use maps with the North = Up orientation to aid planning. However, in order to execute the plan (travel the route), route information and landmarks are more important. The North = Up orientation--even of the cognitive map--interferes with the traveler's ability to deal with route choices (particularly left vs. right choices). This has also been found with pilots using a fixed earth (North = Up) display of bearings. They have a hard time navigating when they are actually flying south. Wickens makes some points about the importance of having exemplars (landmarks) instead of only having the structure (survey knowledge) when it comes to actually navigating the course.

APPENDIX C: PUBLICATIONS

ADAPTIVE DECISION AIDING FOR OFF-ROAD NAVIGATION

Leslie A. Whitaker

Klein Associates Inc.
800 Livermore Street
P.O. Box 264
Yellow Springs, OH 45387-0264
513/767-2691

Grayson Cuqlock-Knopp

Human Engineering Laboratory
SLCHB-CC-LRD
Aberdeen Proving Ground, MD 21005
301/278-5988

February 27, 1990

Presented at the 7th Annual Workshop on Command and Control Decision Aiding, Dayton, OH.

instance. We have found this method of knowledge elicitation to be very helpful in discovering central cues, goals, and actions in a variety of domains (Klein et al., 1989; Klein, 1989).

Measuring Individual Differences

Previous work examining c   ad navigation (e.g., Streeter & Vitello, 1986) has reported significant individual differences in ap reading ability. Good navigators (by self-report) tend to use maps and differentially value landmarks along their routes. In contrast, poor navigators do not use maps and value all landmarks equally.

Sholl (1988) has found that self-report of a "good sense of direction" is correlated with ability to manipulate spatial information mentally. People with a poorer sense of direction took longer to point in the direction of unseen targets. This did not seem to be related to poorer ability to handle spatial information, but instead to difficulty imagining themselves in different orientations.

These individual differences must be considered in the development of any adaptive navigation aid. We are planning a study to examine this issue. Various batteries of tests have been used to provide profiles of good vs. poor navigations. We have selected a battery which measures spatial and verbal skills, maze tracing, and map planning. In addition, we are using tests drawn from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harmon, & Dermen, 1976).

All subjects will be asked to view black-and-white slides produced from photographs of natural scenes, for example, the view along a trail through woodland with a fallow field on the left and a bridge across a narrow stream ahead. The subject will then be shown a set of four alternative views. Only one will be of the same location viewed from a different direction. The task will be to select the correct alternative.

This matching task may be accomplished by mentally rotating a representation of the original scene (Shepard, 1964). Classical evidence for mental rotation is found by examining response latency. Latency increases with an increase in the difference between the angle of regard of the initial target image and that of the correct alternative in the response set. If subjects do mentally rotate the photographs in order to select a match, this process will require the rotation of conceptually three-dimensional images (Barfield, Sandford, & Foley, 1988; Shepard & Metzler, 1971). Barfield et al. found that subjects did use mental rotation (i.e., the classical latency effect was observed) and that they were faster but not consistently more accurate when more realistic representations of objects were used.

Degraded Images Using Teleoperators

The importance of the image's realism will be tested in the third phase of this research plan. Modern technology has increased our capabi ties to send remotely piloted vehicles into hostile environments. In this way, humans are not subjected to more risk than is necessary to accomplish the mission. These remotely operated vehicles are known as teleoperators (Uttal, 1989). Unlike a driver of an automobile or a soldier on foot, "drivers" of teleoperators are not physically present in the environment of the vehicle. Any visual cues are transmitted to them via remote sensors. Visual information can be transmitted directly (i.e., not transformed into a graphical representation) via television cameras mounted on the remote vehicle. From these cameras, the operator must receive the information needed to control the remote vehicle and to navigate.

Drivers of teleoperators cannot visually preview the consequences of their control actions. These operators must be able to imagine what these consequences will be, and then compare this image with the change in the scene that is produced by their steering actions. In the case of a turn, the operator must be able to imagine portions of the scene rotated to a different angle. Wider field of view (FOV) and higher resolution are important for maintaining a sense of orientation.

In conflict with this need for increased FOV and resolution is the military's need to limit transmission band width. All other things being equal, smaller band width reduces both the vehicle's signature (i.e., the ease of its being detected) and the expense of the transmission system. Therefore, FOV and resolution will be varied to determine the limits at which band width can be minimized without undue deterioration in control and navigation performance. Greene (1988) has reported that FOV and resolution can be traded off in night vision systems. In the present research program, similar parametric testing will be used to study the performance of teleoperator controllers during daytime navigation.

One means of achieving better resolution even with limited band width is to use stereoscopic transmissions. Twin cameras can be mounted on the vehicle. Stereoscopic low-resolution images can be fused to produce better quality images. Spacing the cameras by more than the width of a human's eyes aids depth perception. Transmitting low-resolution color from one and high-resolution black-and-white from the other camera produces a moderate quality color image for the controller (Uttal, 1989). These and similar tricks can be used to take advantage of the powers of the human's perceptual system. In this way, better images and improved performance can be obtained without a necessary increase in transmission band width.

Conclusions

The goal of this research is to develop a model of human off-road navigation and its visual requirements. Working from this model, navigation aids can be developed which will help in-vehicle drivers and on-foot soldiers, as well as aid the remote vehicle operator. The aids designed for on-location use will supplement the rich visual information available to the human eye. Under these circumstances, often the difficulty is to make sense of a bewildering array of cues. The aid will be designed to help the navigators select and integrate the information in their environment. In contrast, the difficulty for the remote vehicle operator centers on the lack of direct visual information. This problem can be relieved by supplementing any televised scene information with graphical, transformed information. The selection of this information and the means of displaying it will be directed by the navigation model constructed from this research program.

References

Barfield, W., Sandford, J., & Foley, J. (1988). The mental rotation and perceived realism of computer-generated three-dimensional images. International Journal of Man-Machine Studies, 29, 669-684.

Ekstrom, R. B., French, J. W., Harmon, H. H., & Dermen, D. (1976). Manual for kit of factor-referenced cognitive tests. Princeton, NJ: Educational Testing Service.

Greene, D. A. (1988). Night vision pilotage system field-of-view (FOV)/resolution tradeoff study flight experiment report. Report No. NV1-26, Center for Night Vision and Electro. Optics, Ft. Belvoir, VA.

Klein, G. A. (1989). Recognition-primed decisions. In W. Rouse (Ed.), Advances in Man-Machine Systems Research, 5, 47-92. Greenwich, CT: JAI Press, Inc.

Klein, G. A., Calderwood, R., & MacGregor, D. (1989). Critical decision method for eliciting knowledge. IEEE Transactions on Systems, Man, and Cybernetics, 19(3), 462-472.

Shepard, R. N. (1964). Attention and the metric structure of the stimulus space. Journal of Mathematical Psychology, 1, 54-87.

Shepard, R., & Metzler, J. (1971). Mental rotation of three-dimensional objects. Science, 171, 701-703.

Sholl, M. J. (1988). The relation between sense of direction and mental geographic updating. Intelligence, 12, 299-314.

Streeter, L. A., & Vitello, D. (1986). A profile of drivers' map-reading abilities. Human Factors, 28(2), 223-239.

Uttal, W. R. (1989). Teleoperators. Scientific American, December, 124-129.

Look Where We're Going

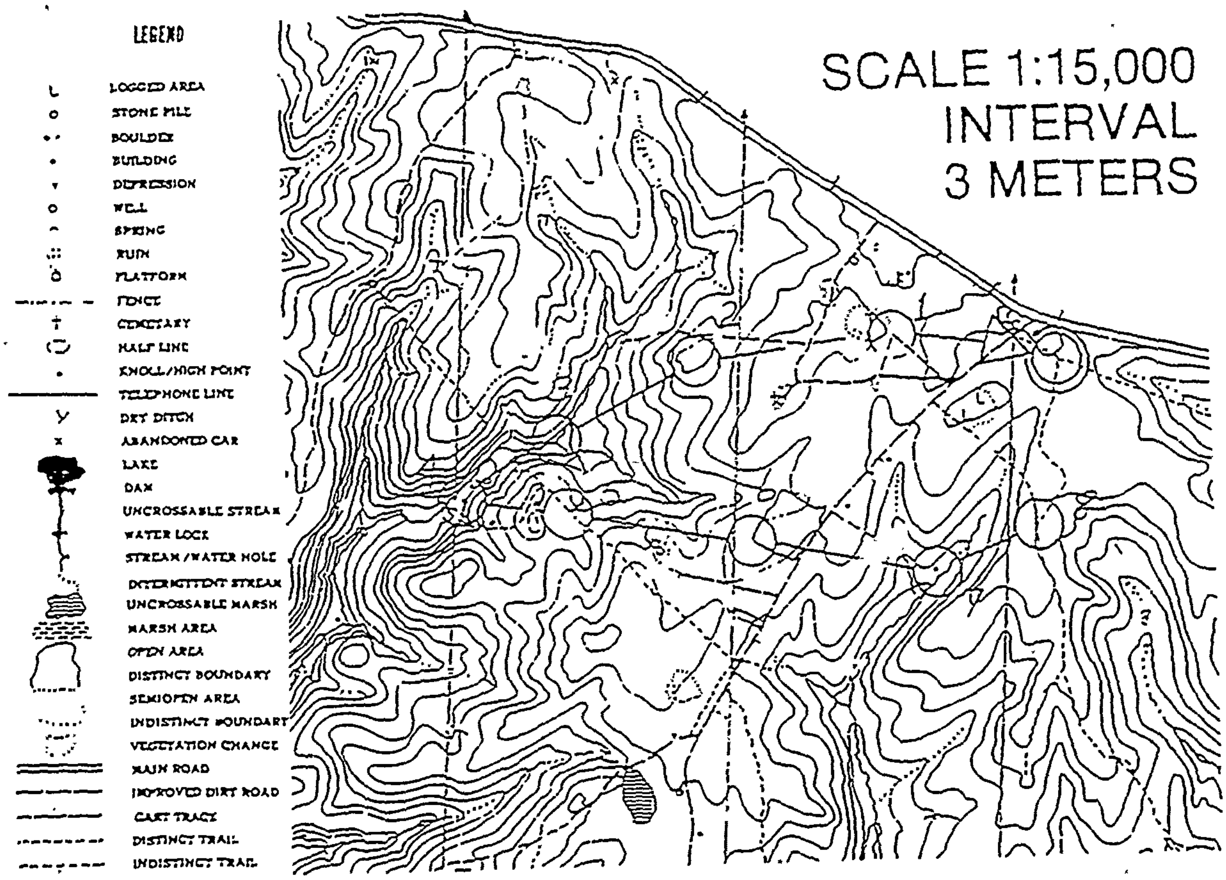
Leslie Whitaker

Off-road navigation is a component of many work and recreation related tasks. These include troop and vehicle movement, as well as logistics and support for the military. In addition, the recreational activities of hunters, hikers, and orienteers require off-road navigational skills.

Dr. Leslie Whitaker, Klein Associates, and Dr. Grayson Cuqlock, Human Engineering Laboratory, are currently conducting interviews with orienteers in the Dayton and Cincinnati area. Their goal is to determine (a) the navigational strategies and (b) the visual cues used by orienteers competing in cross-country meets. These interviews are the first data in a series of studies to be conducted over the next several years by these investigators.

The objective of the research program is the development of an adaptive decision aid to support off-road navigation. The initial phase of this effort is the development of a cognitive model which describes the visual cues and cognitive processes used by navigators. This model will then be used to guide the development of a prototype system.

The investigators plan to publish a summary of their interview results in this Newsletter at a later date. Please watch for this article. In the meantime, if you have any suggestions, ideas, insights or questions, please contact Leslie Whitaker at (513)767-1304 (evenings) or at (513) 767-2691. Dr. Cuqlock can be contacted at (301)278-5988. Next fall, Leslie will be an Associate Professor at the University of Dayton in the Dept. of Psychology. Her phone number there will be (513)229-2713.



Orienteering started in Scandinavia around 1920. The objective is to find the checkpoints (called "controls", indicated by the circles) as quickly as possible, using map, compass and skill. The maps are basically topographical with additional detail relevant to pedestrian cross-country movement and navigation, such as vegetation type (color coded), knolls, depressions and fences. It is a popular sport abroad, and participation is increasing in the USA. The World Championships will be held in America in 1993.